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(54) **METHOD FOR FABRICATING A MAGNETIC WRITER HAVING HALF SHIELDS**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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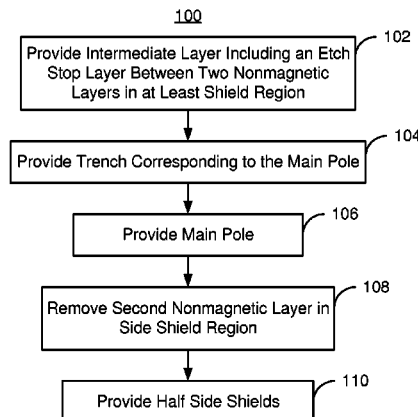
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(57) **ABSTRACT**

A method manufacturing a magnetic writer provides an intermediate layer including multiple sublayers is provided. The sublayers include first and second nonmagnetic layers and an etch stop layer being between the first and second nonmagnetic layers. A trench is formed in the intermediate layer using at least one etch, such as a reactive ion etch. The trench has a location and profile corresponding to the main pole. A main pole having a bottom and a top is provided in the trench. At least a portion of the second nonmagnetic layer is removed using at least a second etch, such as a wet etch process. The etch stop layer is resistant to the at least the second etch. A half side shield is provided on at least part of the first nonmagnetic layer. The half side shield bottom is between the top and the bottom of the main pole.

16 Claims, 6 Drawing Sheets



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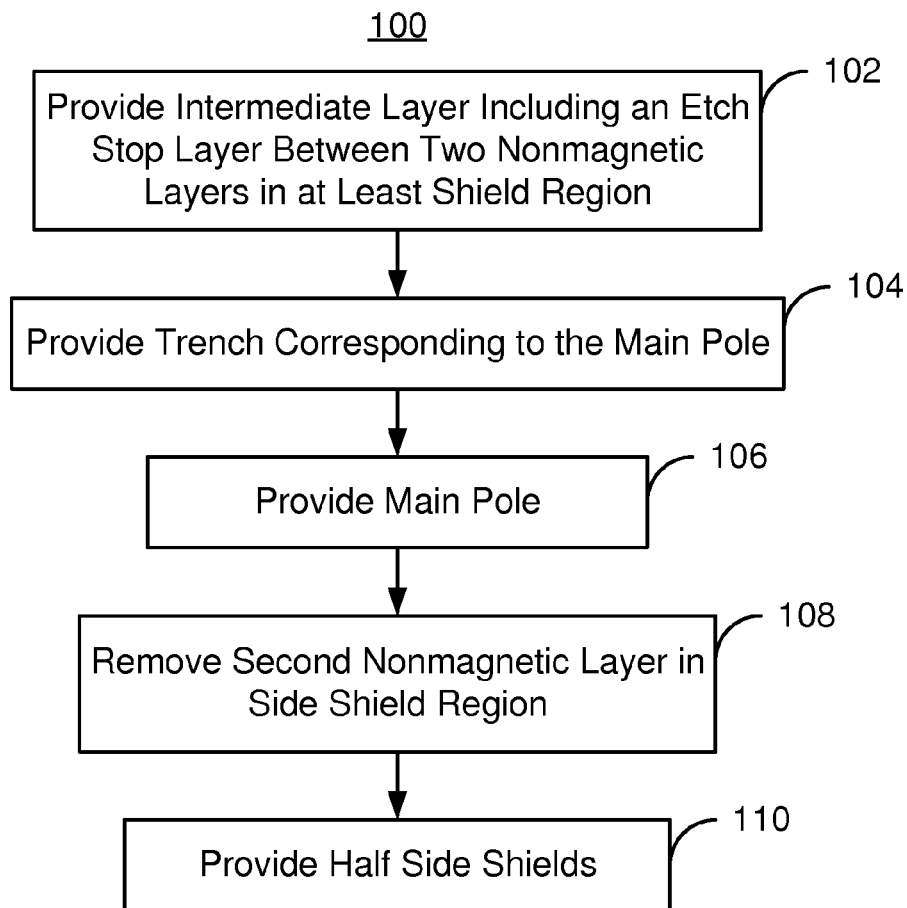
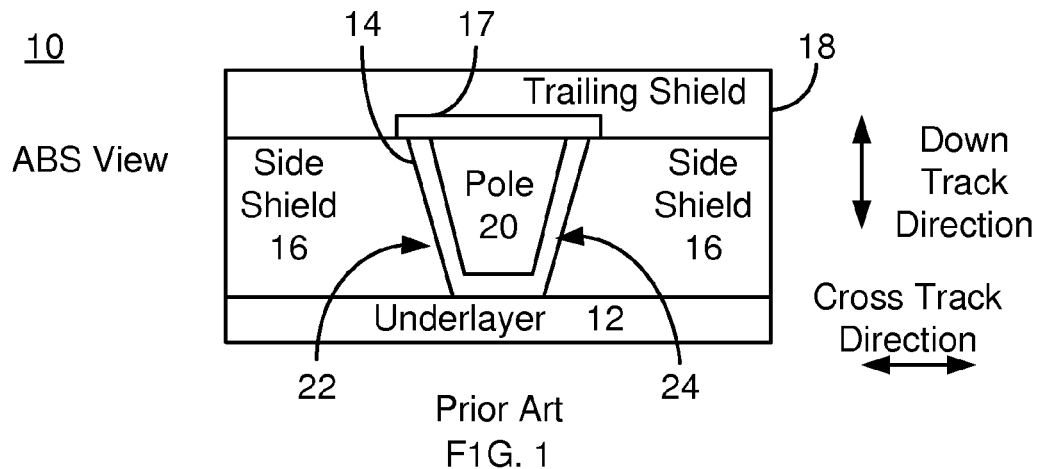


FIG. 2

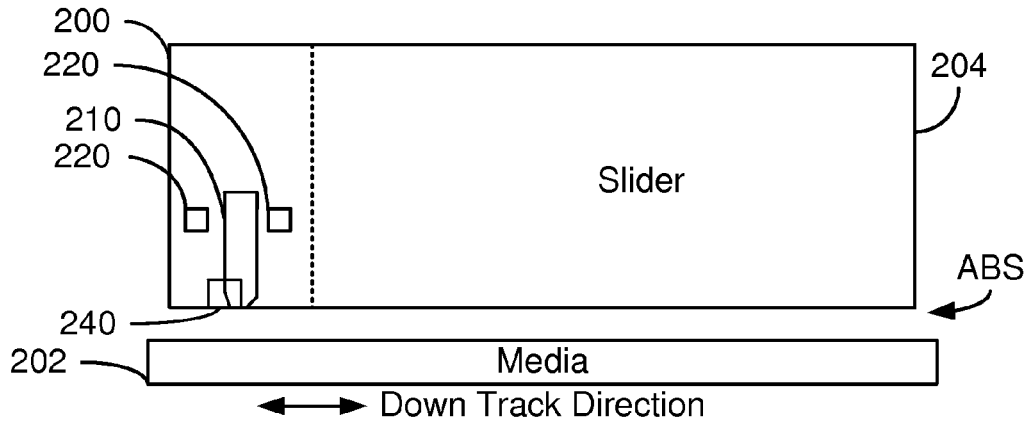


FIG. 3A

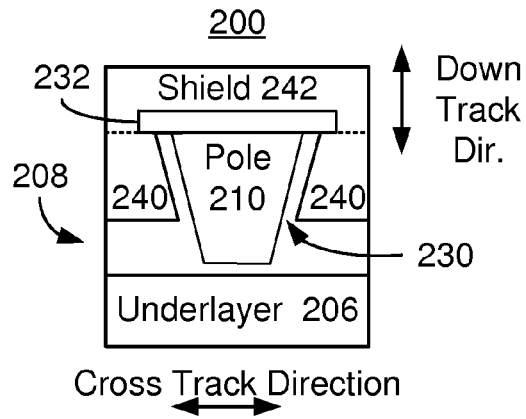


FIG. 3B

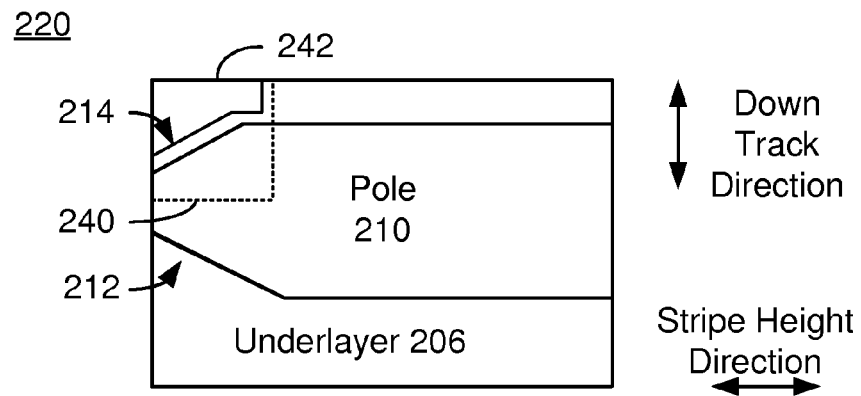


FIG. 3C

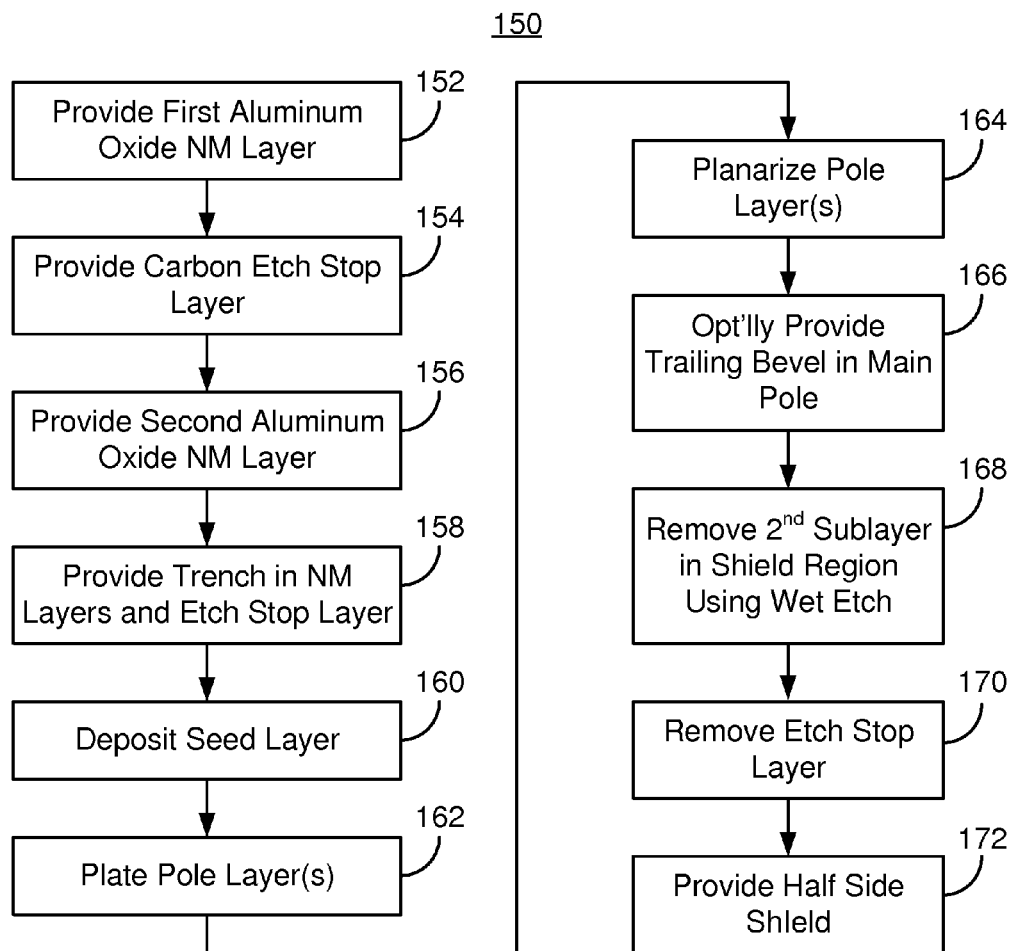


FIG. 4

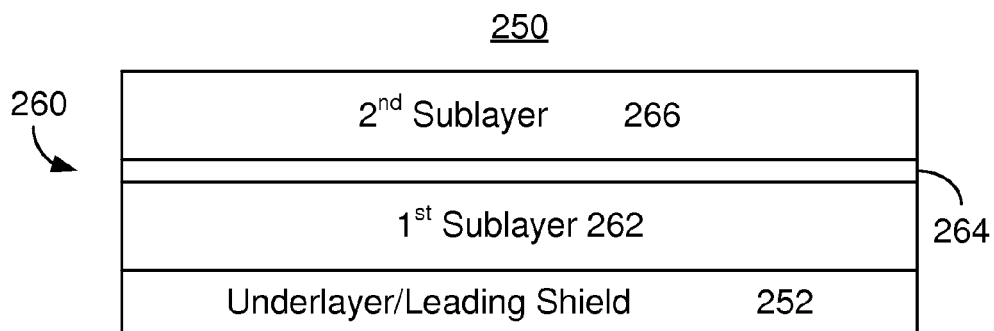


FIG. 5

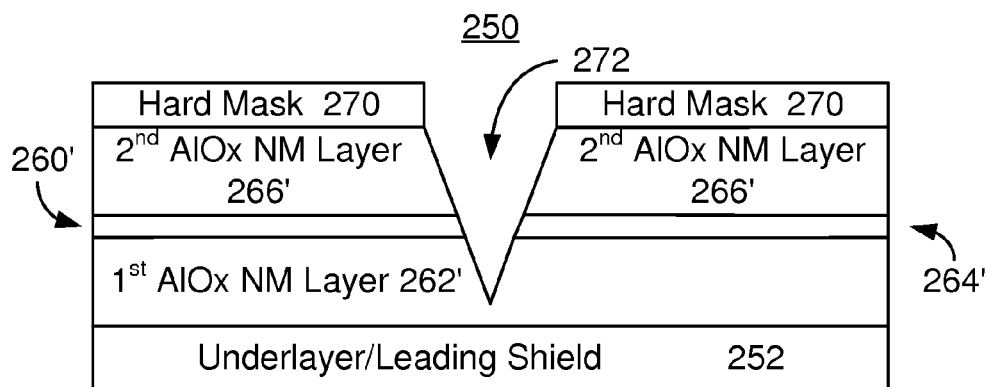


FIG. 6

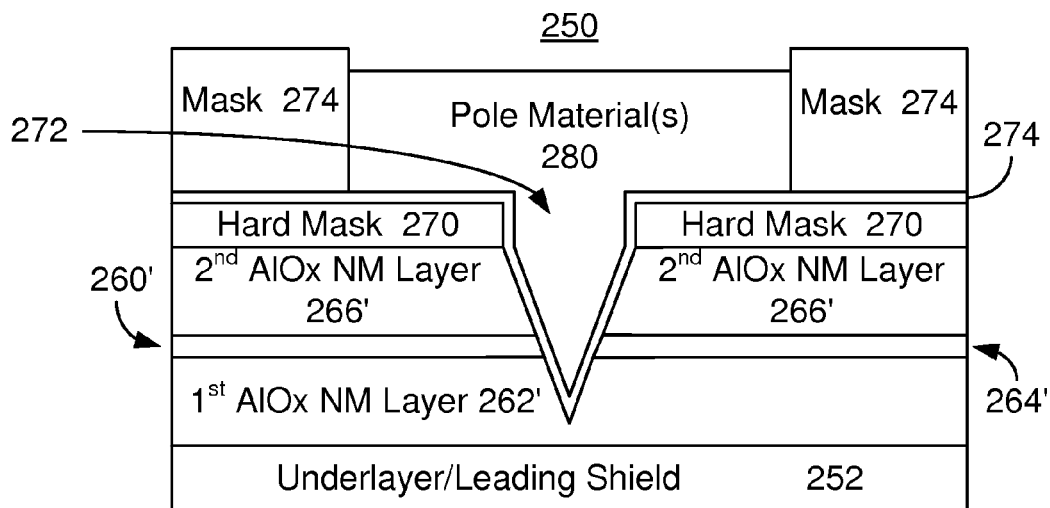


FIG. 7

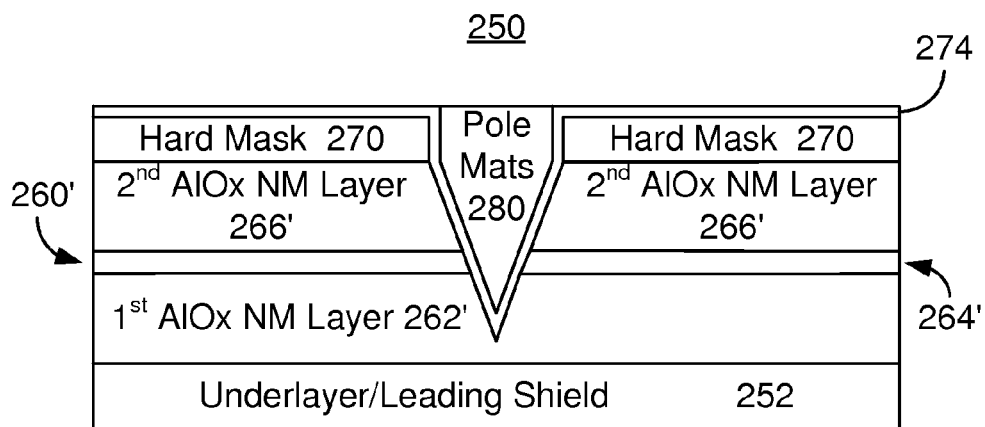


FIG. 8

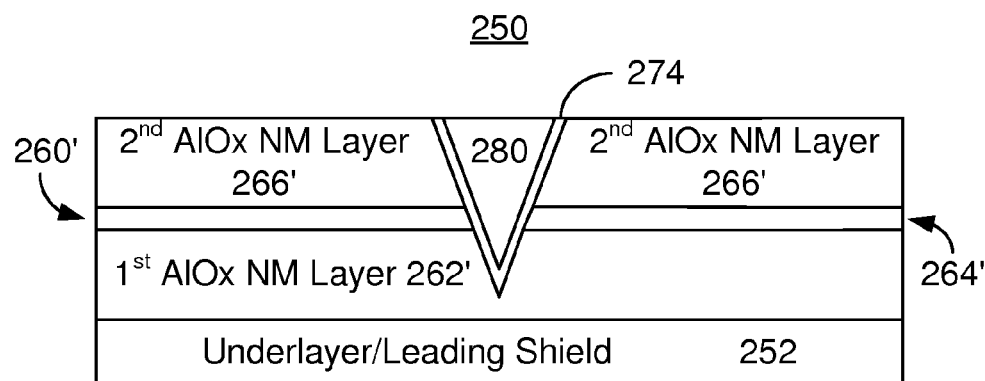


FIG. 9

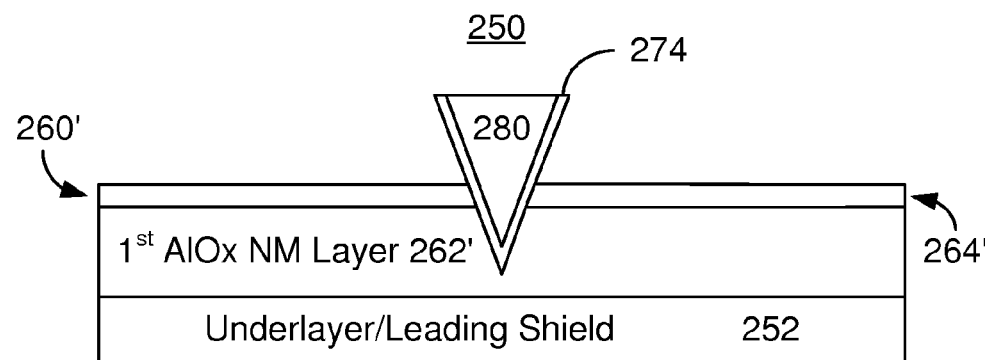


FIG. 10

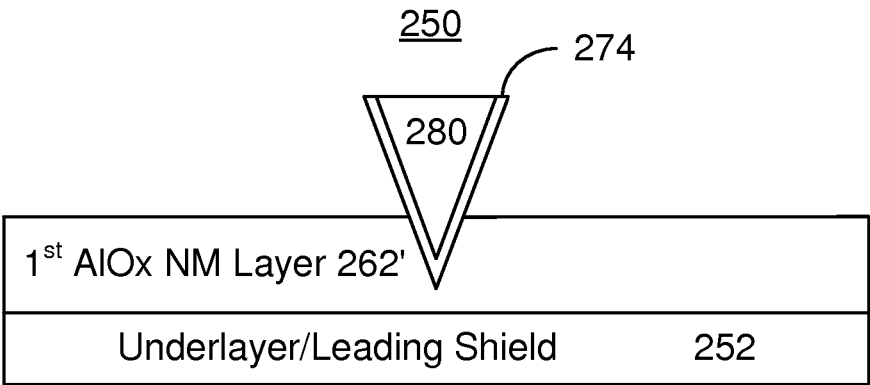


FIG. 11

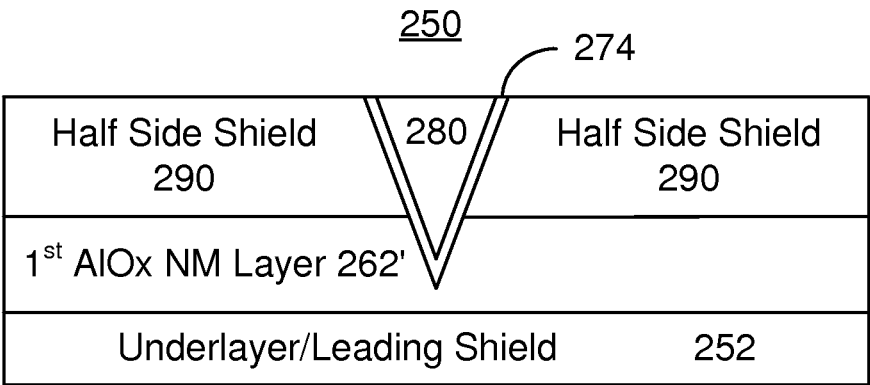


FIG. 12

1

METHOD FOR FABRICATING A MAGNETIC WRITER HAVING HALF SHIELDS

BACKGROUND

FIG. 1 depicts an air-bearing surface (ABS) view of a conventional magnetic recording transducer **10**. The magnetic recording transducer **10** may be a perpendicular magnetic recording (PMR) head. The conventional transducer **10** includes an underlayer **12**, side gap **14**, side shields **16**, top gap **17**, optional top, or trailing, shield **18** and main pole **20**.

The main pole **20** resides on an underlayer **12** and includes sidewalls **22** and **24**. The sidewalls **22** and **24** of the conventional main pole **20** form an angle with the down track direction at the ABS. The side shields **16** are separated from the main pole **20** by a side gap **14**. The side shields **16** extend at least from the top of the main pole **20** to the bottom of the main pole **20**. The side shields **16** also extend a distance back from the ABS. The gap **14** between the side shields **16** and the main pole **20** may have a substantially constant thickness. Thus, the side shields **16** are conformal with the main pole **20**.

Although the conventional magnetic recording head **10** functions, there are drawbacks. In particular, the conventional magnetic recording head **10** may not perform sufficiently at higher recording densities. For example, at higher recording densities, a shingle recording scheme may be desired to be used. In shingle recording, successive tracks partially overwrite previously written tracks in one direction only. Part of the overwritten tracks, such as their edges, are preserved as the recorded data. In shingle recording, the size of the main pole **20** may be increased for a given track size. However, in order to mitigate issues such as track edge curvature, shingle writers have very narrow side gaps **14**. Other design requirements may also be present. The magnetic transducer **10** may not perform as desired or meet the design requirements for such recording schemes. Without such recording schemes, the conventional transducer **10** may not adequately perform at higher areal densities. Accordingly, what is needed is a system and method for improving the performance of a magnetic recording head.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 depicts an ABS view of a conventional magnetic recording head.

FIG. 2 depicts a flow chart of an exemplary embodiment of a method for providing a magnetic recording transducer having half side shields.

FIGS. 3A, 3B and 3C depict side, ABS and apex views of an exemplary embodiment of a magnetic recording disk drive having half side shields.

FIG. 4 depicts a flow chart of another exemplary embodiment of a method for providing half side shields.

FIGS. 5 through 12 depict ABS views of an exemplary embodiment of a magnetic recording transducer fabricated using the method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 depicts an exemplary embodiment of a method **100** for providing a magnetic recording device such as a magnetic recording transducer. For simplicity, some steps may be omitted, interleaved, combined and/or performed in another order. The method **100** is described in the context of providing a single magnetic recording transducer. However, the method

2

100 may be used to fabricate multiple magnetic recording transducers at substantially the same time. The method **100** is also described in the context of particular layers. A particular layer may include multiple materials and/or multiple sublayers. The method **100** also may start after formation of other portions of the magnetic recording head. For example, the method **100** may start after a read transducer, return pole/shield and/or other structure have been fabricated.

An intermediate layer including at least multiple sublayers is provided, via step **102**. In at least the region in which the pole tip and side shields are to be formed (shield region), the intermediate layer includes a first sublayer, a second sublayer and at least one etch stop layer between the first and second sublayers. In some embodiments, the first and second sublayers include the same material, such as aluminum oxide. The etch stop layer is resistance to an etch (such as a wet etch) of the second sublayer. However, the etch stop layer should also be able to be removed when the first and second sublayers are removed by another method, such as a reactive ion etch (RIE). In some embodiments, the etch stop layer is amorphous carbon. In other embodiments, the etch stop layer may be Ta, silicon nitride or an analogous layer. The etch stop layer may also be thin. For example, the amorphous carbon etch stop layer may be not more than fifty Angstrom thick. In some embodiments, step **102** includes full-film depositing a first layer, full film depositing an etch stop layer and full film depositing a second layer. In an embodiment, the portions of these layers outside of the side shield region and pole tip region may be removed. The first and second sublayers and etch stop layer may thus remain in the side shield region. The thicknesses of the first sublayer, the etch stop layer and the second sublayer are configured based on the desired height of the side shields. Thus, the top of the first sublayer and the etch stop layer may be positioned at the location at which the half side shields are desired to terminate. Thus, the intermediate layer may be formed.

A trench is formed in an intermediate layer using one or more etches, via step **104**. The trench formed has the desired geometry and location for formation of the main pole. For example, the top of the trench may be wider than the bottom so that the top of the main pole may be wider than the bottom. The trench extends at least partially into the first sublayer in the shield region. In some embodiments, some or all of the trench may extend through the first sublayer. However, if a leading edge bevel is desired, the bottom of the trench may slope in the down track direction. In such embodiments, the portion of the trench at the ABS may not extend through the first sublayer. However, apertures that are the upper portions of the trench are generally formed in the second sublayer and etch stop layer. In embodiments in which the etch removes the etch stop layer as well as the sublayers, a single etch may be used.

The main pole is provided in the trench, via step **106**. In some embodiments, step **106** includes depositing a seed layer, such as Ru and/or magnetic seed layer(s). High saturation magnetization magnetic material(s) for the pole are also provided. For example, such magnetic materials may be plated and/or vacuum deposited. The material(s) may be planarized. Further, a trailing bevel may be formed in the main pole. Formation of the trailing bevel may include covering a portion of the main pole recessed from the ABS and then ion milling the main pole at an angle from the down track direction. This step may be performed after formation of the side shields. The pole formed in step **106** may be conformal to the trench, nonconformal with the trench, or include both conformal and nonconformal portions.

The second (top) sublayer is removed in at least the side shield region, via step **108**. Step **108** may include performing a wet etch. Thus, the second sublayer may be completely removed in the desired region. The etch stop layer is resistant to the removal process of step **108**. Thus, the underlying first sublayer remains. This is true even in embodiments in which the first and second sublayers may be formed of the same material. In some embodiments the etch stop layer may be removed after step **108**.

The half side shield(s) are provided in the shield region, via step **110**. Step **110** may include plating or otherwise providing the material(s) for the side shields. Because of the presence of the first sublayer, the half side shields do not reach the bottom of the main pole. The distance from the bottom of the main pole that the side shields terminate depends upon the thickness of the first sublayer. Although termed "half" side shields, the side shields need not extend precisely halfway down between the top and bottom of the main pole on either side of the main pole. Instead, the half side shields may terminate somewhere between the top and bottom of the main pole.

Using the method **100**, a magnetic transducer having improved performance may be fabricated. A shingle writer may not need to have side shield(s) which extend to the bottom of the main pole. Thus, the method **100** may provide a main pole that may be used in shingle recording. Thus, the benefits of shingle recording may be exploited. The location of the bottom of the half side shields may be set by the thicknesses of the first and second gap layers as well as the location of the etch stop layer. Thus, the side shield geometry may be tailored. In addition, the first and second sublayers may be formed of the same material, such as aluminum oxide. As a result, the processing may be simplified. Characteristics, such as lapping, etching and the thermal properties, may be more consistent. Thus, fabrication and performance of the transducer may be improved.

FIGS. **3A**, **3B** and **3C** depict various views of a transducer **200** fabricated using the method **100**. FIG. **3A** depicts a side view of the disk drive. FIGS. **3B** and **3C** depict ABS and apex (side/cross-sectional) views of the transducer **200**. For clarity, FIGS. **3A-3C** are not to scale. For simplicity not all portions of the disk drive and transducer **200** are shown. In addition, although the disk drive and transducer **200** are depicted in the context of particular components other and/or different components may be used. For example, circuitry used to drive and control various portions of the disk drive is not shown. For simplicity, only single components are shown. However, multiples of each components and/or their sub-components, might be used. The disk drive **200** may be a perpendicular magnetic recording (PMR) disk drive. However, in other embodiments, the disk drive **200** may be configured for other types of magnetic recording included but not limited to heat assisted magnetic recording (HAMR).

The disk drive includes a media **202**, and a slider **204** on which a transducer **200** have been fabricated. Although not shown, the slider **204** and thus the transducer **200** are generally attached to a suspension. In general, the slider **204** includes the write transducer **200** and a read transducer (not shown). However, for clarity, only the write transducer **200** is shown.

The transducer **200** includes an underlayer **206**, an intermediate layer **208**, a main pole **210**, coil(s) **220**, side gap **230**, write gap **232** and half side shields **240**. The underlayer **206** may include a bottom (or leading edge) shield. The coil(s) **220** are used to energize the main pole **210**. Two turns are depicted in FIG. **3A**. Another number of turns may, however, be used. Note that only a portion of the coil(s) **210** may be shown in

FIG. **3A**. If, for example, the coil(s) **220** is a spiral, or pancake, coil, then additional portions of the coil(s) **220** may be located further from the ABS. Further, additional coils may also be used.

The intermediate layer **208** may include one or more sublayers as well as an etch stop layer. However, one or more of the sublayers may have been removed for formation of the gap **230** and half side shields **240**. Although shown as symmetric, the gap **230** may be configured to be asymmetric in the cross track direction.

The main pole **210** is shown as having a top wider than the bottom. The main pole **210** thus includes sidewalls having sidewall angles that are greater than or equal to zero. In an embodiment, these sidewall angles differ at different distances from the ABS. In some embodiments, the sidewall angles at the ABS are at least three degrees and not more than fifteen degrees. In other embodiments, other geometries may be used. For example, the top may be the same size as or smaller than the bottom. The sidewall angles may vary in another manner including, but not limited to, remaining substantially constant. The main pole **210** may be being conformal with the trench in the intermediate layer **208**. In other embodiments, however, at least a portion of the main pole **210** may not be conformal with the sides of the trench. In some embodiments, the main pole **210** may have leading surface bevel **212** and/or a trailing surface bevel **214**, as shown in FIG. **3C**.

The half side shields **240** and a trailing shield **242** are shown as being connected. In other embodiments, the trailing shield **242** may be omitted. This is denoted by a dotted line in FIG. **3B**. In addition, a nonmagnetic gap may be provided between the trailing shield **242** and the half side shields **240**. The half side shields **240** are also shown as having a constant thickness in FIG. **3C**. Stated differently, the bottoms of the half side shields **240** are substantially perpendicular to the ABS. Thus, the dashed line corresponding to the bottoms of the half side shields **240** are perpendicular to the ABS. In other embodiments, the geometry of the half side shields **240** may vary. For example, the bottom of the half side shields **240** track the trailing edge of the pole such that the shield covers less of the pole further from the ABS. In other embodiments, the half side shield thickness may vary. In such embodiments, the bottom of the half shield shields **240** may be parallel to the leading bevel **212** or the trailing bevel **214** while the top surface is perpendicular to the ABS. Other variations are also possible. However, note that bottoms of the half shields reside on the top of the intermediate layer **208** is between the top and bottom of the pole **210**.

The magnetic transducer **200** in the disk drive may be used in shingle recording. Thus, the benefits of shingle recording may be achieved. For example, higher areal density recording may be performed by a head having larger critical dimensions.

FIG. **4** depicts an exemplary embodiment of a method **150** for providing a pole and half side shields for a magnetic recording transducer. For simplicity, some steps may be omitted, interleaved, performed in another order and/or combined. FIGS. **5-12** depict ABS views of an exemplary embodiment of a magnetic recording transducer **250** during fabrication. The method **150** is described in the context of providing a magnetic recording transducer **250** depicted in FIGS. **5-12** depict ABS views of an exemplary embodiment of a transducer **250** during fabrication using the method **150**. Referring to FIGS. **4-12**, the method **150** may be used to fabricate multiple magnetic recording heads at substantially the same time. The method **150** may also be used to fabricate other magnetic recording transducers. The method **150** is also

described in the context of particular layers. A particular layer may include multiple materials and/or multiple sub-layers. The method 150 also may start after formation of other portions of the magnetic recording transducer. For example, the method 150 may start after a read transducer, return pole/shield and/or other structure have been fabricated.

The material(s) for the first sublayer are full-film deposited, via step 152. In some embodiments, step 152 includes full-film depositing aluminum oxide. The materials for the etch stop layer are provided, via step 154. Step 154 may include full-film depositing amorphous carbon, Ta or silicon nitride or another material that is resistant to an aluminum oxide wet etch. The material(s) for the second sublayer are provided, via step 156. Step 156 may include full-film depositing another aluminum oxide layer. Thus, the layers provided in step 152 and 156 are desired to be formed of the same material. In addition, steps 152, 154, and 156 may be carried out so that the structure including two sublayers separated by the etch stop layer are only in the shield region. Steps 152, 154 and 156 form the intermediate layer.

FIG. 5 depicts an ABS view of the transducer 250 after step 156 has been performed. Thus, the first aluminum oxide sublayer 262 has been provided on the underlayer 252. The underlayer 252 may include a leading shield. The etch stop layer 264 has been deposited on the first sublayer 262. The second sublayer 266 has been provided on the etch stop layer 264. Thus, the first sublayer 262 and second sublayer 266 may be aluminum oxide while the etch stop layer 264 may be amorphous carbon, tantalum or silicon nitride. Other materials may be used, but the first and second sublayers are generally desired to be formed of the same material(s). The etch stop layer 264 is desired to be resistant to at least some etches of the layer 262 and 266, but removable using other etches that are the same as for the layers 262 and 266. The etch stop layer 264 is desired to be thin, for example on the order of five nanometers or less. The thicknesses of the layers 262, 264 and 266 may be selected such that the half shields extend to the top of the first sublayer 262. The layers 262, 264 and 266 form at least part of the intermediate layer 260. The total thickness of the intermediate layer 260 may be at least that desired for the main pole.

A trench is formed in the intermediate layer, via step 158. Step 158 may include multiple substeps. For example, a mask including an aperture that corresponds to a trench may be provided on the intermediate layer 260. The mask may be a hard mask. A trench is formed in region of the intermediate layer 260 that is exposed by the aperture in the hard mask layers. Step 158 may include performing an aluminum oxide RIE (or other RIE(s) appropriate for the layers 262, 264 and 266). In some embodiments, multiple RIEs are used to obtain the desired trench profile for various regions of the transducer 250. FIG. 6 depicts an ABS view of the transducer 250 after step 158 has been performed. Thus, a mask 270 has been provided. In addition, a trench 272 has been formed in layers 262', 264' and 266' (in intermediate layer 260'). In the embodiment shown, the bottom of the trench 272 does not reach the underlayer 252 at the ABS. Thus, apertures are formed in layers 264' and 266', but a groove formed in at least part of the layer 262'. However, the trench 272 may be deeper at other regions, such as in the yoke region. Thus, the pole being formed may have a leading edge bevel. In the embodiment shown, the trench 272 has a triangular profile at the ABS. In other embodiments, the bottom of the trench 272 may have a trapezoidal shape at the ABS. The trench 272 resides below an aperture in the mask 270.

Seed layer(s) that are resistant to an etch of the intermediate layer 260 is deposited in the trench, via step 160. In some

embodiments, this seed layer may serve as at least part of the gap. The seed layer may include material(s) such as Ru deposited using methods such as chemical vapor deposition. In other embodiments, a magnetic seed layer may be used in lieu of or in addition to a nonmagnetic seed layer. If an asymmetric gap is desired, then part of trench 272 may be covered by a mask and additional gap layers deposited.

The material(s) for the main pole may then be provided, via step 162. Step 162 includes depositing high saturation magnetization magnetic material(s), for example via electroplating. In some embodiments, the pole materials provided in step 162 fills the trench 272. However, in other embodiments, the pole may occupy only a portion of the trench. FIG. 7 depicts an ABS view of the transducer 250 after a step 162 has been performed. Thus, the seed/gap layer 274 and pole materials 280 have been provided. A leading bevel may be naturally formed in the magnetic pole to the shape of the trench 272 and the deposition techniques used.

A planarization, such as a chemical mechanical planarization (CMP) may also be performed, via step 164. In some embodiments, a trailing edge (top) bevel may be formed, via step 166. In other embodiments, however, the trailing bevel may be formed later. A mill may also be used to remove the mask 270. FIG. 8 depicts an ABS view of the transducer 250 after step 166 has been completed. Thus, the portion of the main pole materials outside of the trench has been removed, forming main pole 280. The main pole 280 has a triangular cross section at the ABS.

A portion of the second sublayer 266 may be removed in at least the side shield region, via step 168. In particular, a portion of the second sublayer adjacent to the first side of the main pole 280 may be removed in at least the region in which the shields are to be formed. Step 168 includes providing a mask that covers the main pole 280 and the second sublayer 266' in regions outside of the side shield region. In some embodiments, the removal of the second sublayer may be performed using a wet etch, such as an aluminum oxide wet etch. After the etch, the mask may be removed. FIG. 10 depicts the transducer 250 after step 168 has been performed. Thus, the second sublayer 266' has been removed. Thus, the remaining intermediate layer 260' includes the first sublayer 262' and the etch stop layer 264'.

The etch stop layer is removed, via step 170. FIG. 11 depicts an ABS view of the transducer 250 after step 170 is performed. Thus, the top of the aluminum oxide layer 262' is exposed.

The half side shield(s) may be provided, via step 172. Step 172 may include depositing a seed layer as well as the material(s) for the shields. For example, a seed layer may be deposited, followed by electroplating of a magnetic material such as NiFe. FIG. 12 depicts an ABS view of the transducer 250 after step 172 has been performed. Thus, the half shield 290 is shown. As can be seen in FIG. 12, the shield 290 terminates between the top and the bottom of the main pole 280. In the embodiment shown, the half side shield 290 terminates near the top of the main pole 280. In other embodiments, the half side shield 290 may be physically and magnetically connected to a trailing shield (not shown in FIG. 12). In such an embodiment, the trailing shield and half side shield may be deposited together.

Using the method 150, the transducer 250 including shield 290 may be provided. Thus, the benefits of shingle recording may be achieved. For example, higher areal density recording may be performed by a head having larger critical dimensions.

We claim:

1. A method for fabricating magnetic write apparatus having air-bearing surface (ABS) location comprising:

providing an intermediate layer including a plurality of sublayers, the plurality of sublayers including a first nonmagnetic layer, an etch stop layer and a second nonmagnetic layer, the etch stop layer being between the first nonmagnetic layer and the second nonmagnetic layer;

forming a trench in the intermediate layer using at least one etch, the trench having a location and profile corresponding to a main pole;

providing the main pole in the trench, the main pole having a top and a bottom;

removing at least a portion of the second nonmagnetic layer using at least a second etch, the etch stop layer being resistant to the at least the second etch; and

providing a half side shield on at least a portion of the first nonmagnetic layer, a half side shield bottom of the half side shield being between the top and the bottom of the main pole.

2. The method of claim 1 wherein the first nonmagnetic layer consists of at least one nonmagnetic material, the second nonmagnetic layer consists of the at least one nonmagnetic material.

3. The method of claim 2 wherein the at least one nonmagnetic material is reactive ion etchable and wet etchable.

4. The method of claim 2 wherein the at least one nonmagnetic material is aluminum oxide.

5. The method of claim 1 wherein the step of providing the main pole further includes:

providing the main pole having the bottom, the top wider than the bottom, a first side and a second side opposite to the first side.

6. The method of claim 1 further comprising:

providing a side gap layer before the step of providing the main pole, at least a portion of the side gap layer residing in the trench.

7. The method of claim 1 further comprising:

removing the etch stop layer after the step of removing the at least the portion of the second nonmagnetic layer.

8. The method of claim 1 wherein the etch stop layer is removable using an etch which does not remove the first nonmagnetic layer.

9. The method of claim 1 wherein the etch stop layer is at least one of a carbon layer, a Ta layer, and a silicon nitride layer.

10. The method of claim 1 wherein the at least the second etch is a wet etch of the at least the portion of the second nonmagnetic layer.

11. The method of claim 1 wherein the step of providing the main pole further includes:

providing at least one main pole layer;

planarizing the at least one main pole layer a remaining portion of the at least one main pole layer having a bottom, a top wider than the bottom, a first side and a second side opposite to the first side; and

forming a trailing bevel in the main pole layer.

12. The method of claim 1 wherein the step of providing the intermediate layer further includes:

full-film depositing the first nonmagnetic layer;

full-film depositing the etch stop layer on the first nonmagnetic layer; and

full-film depositing the second nonmagnetic layer on the etch stop layer.

13. The method of claim 1 wherein the step of forming the trench further includes:

forming a trench using a single etch.

14. The method of claim 13 wherein the trench has a plurality of sidewalls extending through the first nonmagnetic layer, the second nonmagnetic layer and the etch stop layer, the sidewalls having substantially the same angle in the first nonmagnetic layer, the second nonmagnetic layer and the etch stop layer.

15. The method of claim 4 wherein the at least the second etch is a wet etch of the at least the portion of the second nonmagnetic layer.

16. A method for fabricating a magnetic transducer having air-bearing surface (ABS) location and an intermediate layer comprising:

full-film depositing a first nonmagnetic layer in at least a side shield region;

full-film depositing an etch stop layer on the first nonmagnetic layer in the at least the side shield region;

full-film depositing a second nonmagnetic on the etch stop layer in the at least the side shield region, the first nonmagnetic layer, the second nonmagnetic layer and the etch stop layer forming an intermediate layer, the first nonmagnetic layer consisting of at least one nonmagnetic material, the second nonmagnetic layer consisting of the at least one nonmagnetic material, the at least one nonmagnetic material being wet etchable and reactive ion etchable;

forming a trench in the intermediate layer using a reactive ion etch, the trench including a first portion in the first nonmagnetic layer, a second portion in the second nonmagnetic layer and a third portion in the etch stop layer, the first portion, the second portion and the third portion of the trench having a plurality of sidewalls with substantially sidewall angles;

depositing a seed layer, a portion of the seed layer residing in the trench;

depositing at least one main pole layer;

planarizing the at least one main pole layer;

providing a trailing bevel in a remaining portion of the main pole layer, thereby forming a main pole having a bottom, a top wider than the bottom, a first side and a second side opposite to the first side;

removing a portion of the second nonmagnetic in the side shield region using a wet etch, thereby exposing a portion of the etch stop layer in the side shield region;

removing the portion of the etch stop layer, thereby exposing an exposed portion of the first nonmagnetic layer in the side shield region; and

providing a half side shield on the exposed portion of the first nonmagnetic layer, a bottom of the half side shield being between the top and the bottom of the main pole.

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